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# M31-RV evolution and its alleged multi-outburst pattern*

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**Abstract.** The photometric evolution of M31-RV has been investigated on 1447 plates of the Andromeda galaxy obtained over half a century with the Asiago telescopes. M31-RV is a gigantic stellar explosion that occurred during 1988 in the Bulge of M31 and that was characterized by the appearance for a few months of an M supergiant reaching $M_{bol} = -10$. The 1988 outburst has been positively detected on Asiago plates, and it has been the only such event recorded over the period covered by the plates (1942-1993). In particular, an alleged previous outburst in 1967 is excluded by the more numerous and deeper Asiago plates, with relevant implication for the interpretative models of this unique event. We outline a close analogy in spectral and photometric evolution with those of V838 Mon which exploded in our Galaxy in 2002. The analogy is found to extend also to the closely similar absolute magnitude at the time of the sudden drop in photospheric temperature that both M31-RV and V838 Mon exhibited. These similarities, in spite of the greatly differing metallicity, age and mass of the two objects, suggest that the same, universal and not yet identified process was at work in both cases.

**Key words.** Stars: AGB and post-AGB – Stars: novae – Stars: peculiar – Stars: individual: V838 Mon – Stars: individual: M31-RV – Galaxies: individual: M31

## 1. Introduction

Rich et al. (1989) discovered in 1988 a highly unusual stellar outburst in the Bulge of the Andromeda galaxy (M31), known since then as M31-RV (for "red variable"). The event peaked at $M_{bol} \approx -10$ mag and its spectrum closely resembled that of M supergiants, evolving from M0 I at discovery (Sept 5, 1988) to >M7 I about 58 days later when the brightness in the $V$ band had dropped by at least 4 mag (Rich 1990). Two similar events have been later identified in our Galaxy, V4332 Sgr that exploded in 1994 (Martini et al. 1999) and V838 Mon that erupted in 2002 (Munari et al. 2002a, Bond et al. 2003, and references therein).

The M31-RV event has been characterized by radiative luminosities in-between those of classical novae and supernovae. The mass of the ejected envelope (optically thick during the whole observed evolution) is uncertain but it is certainly larger than in typical novae and much less than in supernovae. The radiative and kinetic energetics place therefore M31-RV, and by analogy also V4332 Sgr and V838 Mon, in the gap between classical novae and supernovae, making them stars of special interest. So far, few theoretical attempts to explain their highly peculiar nature have been pursued. Soker and Tylenda (2003), to explain the energetics and multi-maxima behaviour of V838 Mon, have suggested the merging of two main sequence stars of masses 0.1−0.5 $M_\odot$ and 1.5 $M_\odot$, with the second one expanding to large radii, low temperature and high luminosity in response to the frictional energy dissipation of the cannibalized less massive companion. A similar scenario has been proposed by Retter and Marom (2003). They postulated the multi-maximum eruption of V838 Mon as the result of the swallowing of massive planets in close orbit around a parent star expanding while on the RGB (red giant branch) or AGB (asymptotic giant branch). A thermonuclear runaway (TNR) model was instead developed by Iben and Tutukov (1992) to explain M31-RV. The model envisages a binary system, composed of a WD and a low mass companion, that evolves to orbital periods shorter than 2 hours by loss of angular momentum via gravitational waves, without experiencing classical nova eruptions on the way to. The accretion at very low rates ($\sim 10^{-11}$ $M_\odot$ yr$^{-1}$) occurring onto a cold white dwarf (WD) can lead to the accumulation of a massive H-rich envelope of the order of ∼0.05 $M_\odot$ before this is expelled in a gigantic hydrogen shell flash (some $10^3$ times the mass expelled in a typical nova eruption). Friction energy dissipation of the binary revolving within such a massive and dense common envelope can raise the drag lu-

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* Table 3 available only in electronic form (ASCII format) at CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/ and from the web page http://ulisse.pd.astro.it/M31-RV/, where further information is provided

**Table 1.** Plates of Andromeda galaxy from the Asiago archive inspected in the M31-RV search. The last two columns detail the number of plates obtained in 1988, when the outburst of M31-RV occurred, and in 1967, when an alleged previous outburst should have taken place.

| telescope | | focal length | first plate | last plate | $N_{tot}$ plates | main band | plates in 1967 | plates in 1988 |
|---|---|---|---|---|---|---|---|---|
| 1.22 m | Newton | 6.0 m | 29 Oct 1942 | 26 Aug 1992 | 831 | 795 in $B$ band | 25 | 2 |
| 1.22 m | Cassegrain | 19.1 m | 31 Oct 1961 | 27 Nov 1972 | 94 | 93 in $B$ band | 4 | |
| 1.82 m | Cassegrain | 16.4 m | 05 Aug 1973 | 09 Dec 1988 | 194 | 177 in $B$ band | | 2 |
| 67/92 cm | Schmidt | 2.2 m | 02 Oct 1965 | 17 Dec 1993 | 291 | 264 in $B$ band | 2 | 8 |
| 40/50 cm | Schmidt | 1.0 m | 14 Oct 1958 | 05 Mar 1986 | 37 | 28 in $B$ band | | |

minosity to $10^7$ $L_\odot$, with as much as $10^6$ $L_\odot$ ($\gg L_{\rm Eddington}$) coming out in the form of radiation.

Common to all models above is the uniqueness of the event: the progenitor can experience a single such outburst in its life. In the Soker and Tylenda (2003) and Retter and Marom (2003) approaches, it is the result of a merger event that obviously cannot be repeated. In the Iben and Tutukov (1992) model an extremely long time (a sizable fraction of a Hubble time) is required to accrete at very low rates $10^{-2}$ $M_\odot$ on a WD that had to cool to low temperatures.

Therefore, the report by Sharov (1990) about a second outburst of M31-RV in 1967, 20 years before the main one, is something that deserves careful scrutiny and independent verification. If confirmed, it would have profound consequences on the theoretical modeling of M31-RV, V4332 Sgr and V838 Mon, perhaps even more than the discovery of a massive and young B3 V companion to the latter (Munari et al. 2002b). The recent eruption of V838 Mon has considerably revitalized the interest on this class of objects. In anticipation of a growing modeling effort by the community, we decided to take advantage of the Asiago plate archive to evaluate the reality of a second outburst of M31-RV and to investigate its long term photometric evolution.

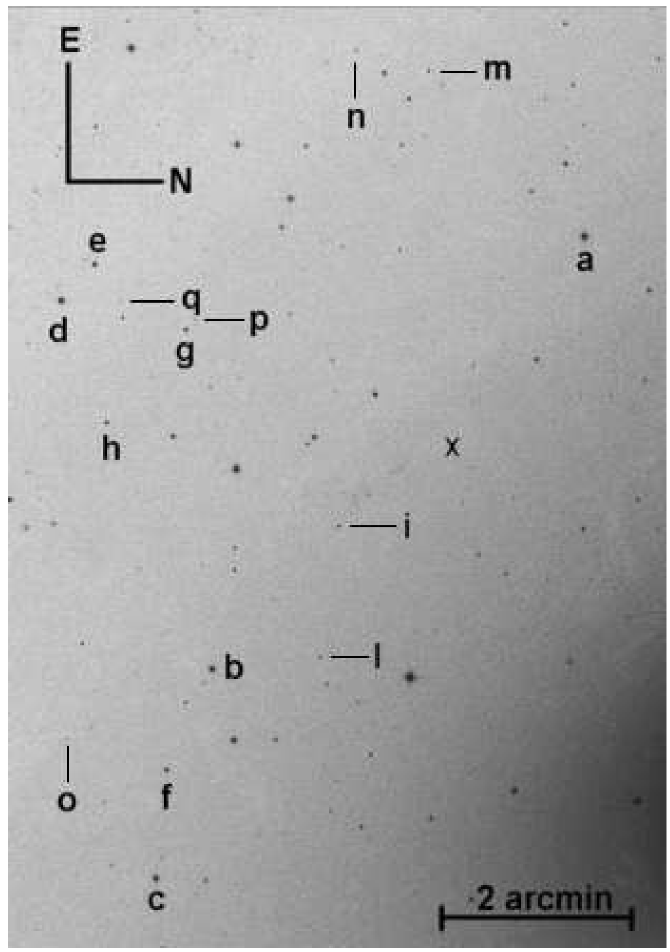


**Fig. 1.** Finding chart for the $BVR_CI_C$ comparison sequence listed in Table 2. The "$X$" marks the location of M31-RV.

## 2. Plate archive data

Four instruments have contributed to the large collection of photographic plates of M31 that we have located in the Asiago archive: the 1.22 m and 1.82 m reflectors, and the 40/50 cm and 67/92 cm Schmidt telescopes. Details about the number of plates, time span, focal length, limiting magnitude, etc. are provided in Table 1.

In total, we have selected and retrieved 1447 plates of M31 from the Asiago archive. They all have been inspected visually with a high quality Zeiss binocular microscope. All plates have been inspected by the same author, and about 10% of them, randomly selected, checked by the other one. All key plates have been inspected by both authors more than once (over a one month time span and each time with a different orientation), taking care to make them unrecognizable so to avoid biasing from memory of previous inspections. The agreement between the estimates of the two authors and their repeatability at different times turned out to be excellent, typically at the 0.05 mag level, and very rarely differing by more than 0.1 mag. Munari et al. (2003) have determined an accurate astrometric position for M31-RV and have provided a finding chart from one of the Asiago plates taken during the 1988 outburst.

**Table 2.** The comparison sequence plotted in Figure 1. Magnitudes from CCD observations of Magnier et al. (1992).

| | $B$ | $V$ | $R_C$ | $I_C$ |
|---|---|---|---|---|
| a | 14.306 | 13.691 | 13.328 | 13.058 |
| b | 14.780 | 14.227 | 13.902 | 13.638 |
| c | 15.039 | 14.695 | 14.463 | 14.269 |
| d | 15.272 | 14.803 | 14.440 | 14.213 |
| e | 16.086 | 15.217 | 14.657 | 14.275 |
| f | 16.644 | 15.881 | 15.487 | 15.233 |
| g | 16.892 | 16.099 | 15.582 | 15.239 |
| h | 17.401 | 16.665 | 16.184 | 15.868 |
| i | 17.775 | 17.154 | 16.820 | 16.662 |
| l | 18.369 | 17.524 | 17.051 | 16.840 |
| m | 18.556 | 18.116 | 17.792 | 17.472 |
| n | 19.043 | 18.176 | 17.649 | 17.275 |
| o | 19.591 | 19.589 | 19.368 | —— |
| p | 20.117 | 19.419 | 18.562 | 17.872 |
| q | 20.363 | 19.729 | 19.308 | 18.981 |

A proper comparison sequence had to be established. We looked for literature data of stars close to M31-RV and projected on similar background brightness (thus roughly aligned parallel to local isophotes of the the unresolved bulge of M31), to minimize biasing by the galaxy background when going from plates of one instrument to those of another, taken with different focal lengths, photometric bands, exposure times, seeing and sky conditions. We selected magnitudes obtained by Magnier et al. (1992) with CCD observations that allowed proper handling of bulge background. The sequence we have adopted is presented in Figure 1 and listed in Table 2. Comparison with other datasets (A. Henden 2003, priv. comm.) indicate that there may be errors in the 0.1 mag range for some of the stars, but using the ensemble results in photometry close to the standard system.

The date, UT, telescope, filter, emulsion, exposure time and limiting magnitude in the appropriate band for each one of the 1447 inspected plates is given in Table 3 (available only in electronic form).

## 3. No outburst in 1967

Sharov (1990) announced that M31-RV had twenty years earlier experienced an outburst similar to that of 1988. He reported that while inspecting a long series of plates of M31 taken with telescopes of the Crimean Astrophysical Observatory he noted M31-RV around $B$ ∼18.5 on three plates taken on Aug 4, Sep 3 and Sep 4, 1967 (Sharov reported that the outburst occurred in 1968, but the JDs he tabulated leave no doubt it was 1967. The listed JDs firmly establish the 50 cm Maksutof telescope as the source instrument. According to A.Tatarnikova (private communication) the focal length of this instrument is 2.0 m).

**Table 4.** Results of the inspection of 1967 and 1988 plates looking for M31-RV. For 1967, to save table length we list only sample plates for non-redundant dates (the whole list is accessible via electronic Table 3). Additional plates for late 1966 and early 1968 are reported for completeness.

| tel. & plate # | | date & UT (dd.mm.yy) | | emuls. & filter | | detect. | limit. mag. |
|---|---|---|---|---|---|---|---|
| | | *M31-RV in 1967* | | | | | |
| 1.22 | 7766 | 21.09.66 | 22:06 | 103a-O | – | no | $B$=19.9 |
| 1.22 | 7850 | 18.11.66 | 18:07 | 103a-O | – | no | $B$=20.1 |
| 1.22 | 7894 | 09.12.66 | 17:33 | 103a-O | – | no | $B$=20.1 |
| 1.22 | 7940 | 13.01.67 | 17:37 | 103a-O | – | no | $B$=20.1 |
| 1.22 | 7950 | 06.02.67 | 18:22 | 103a-O | – | no | $B$=19.8 |
| 1.22 | 8114 | 11.08.67 | 00:19 | 103a-O | – | no | $B$=20.5 |
| 1.22 | 8128 | 27.09.67 | 19:56 | 103a-O | – | no | $B$=20.4 |
| 1.22 | 8162 | 03.10.67 | 20:40 | 103a-O | – | no | $B$=20.1 |
| 1.22 | 8202 | 01.12.67 | 17:53 | 103a-O | – | no | $B$=20.4 |
| 1.22 | 8226 | 27.12.67 | 18:13 | 103a-O | – | no | $B$=20.6 |
| 1.22 | 8243 | 01.01.68 | 18:10 | 103a-O | – | no | $B$=20.1 |
| 1.22 | 8367 | 26.07.68 | 00:08 | 103a-O | – | no | $B$=20.4 |
| 1.22 | 8406 | 25.09.68 | 20:00 | 103a-O | – | no | $B$=20.4 |
| 1.22 | 8436 | 24.10.68 | 22:39 | 103a-O | – | no | $B$=20.4 |
| | | *M31-RV in 1988* | | | | | |
| 67/92 | 13990 | 16.01.88 | 19:25 | 103a-E | RG1 | no | $R$=17.2 |
| 67/92 | 14197 | 13.08.88 | 00:03 | 103a-E | RG1 | $R$=15.0 | $R$=17.5 |
| 67/92 | 14222 | 08.09.88 | 01:27 | 103a-E | RG1 | $R$=15.3 | $R$=17.6 |
| 67/92 | 14244 | 15.10.88 | 21:22 | 103a-D | GG14 | no | $V$=18.2 |
| 1.22 | 9631 | 16.10.88 | 01:00 | 103a-O | GG13 | no | $B$=19.8 |
| 67/92 | 14266 | 07.11.88 | 20:34 | 103a-D | GG14 | no | $V$=18.0 |
| 67/92 | 14293 | 16.11.88 | 01:20 | 103a-E | RG1 | no | $R$=17.2 |
| 67/92 | 14312 | 08.12.88 | 19:57 | 103a-E | RG1 | no | $R$=17.6 |
| 67/92 | 14313 | 08.12.88 | 21:20 | 103a-O | GG13 | no | $B$=18.6 |
| 1.22 | 9643 | 08.12.88 | 21:50 | 103a-O | GG13 | no | $B$=17.8 |
| 1.82 | 3862 | 09.12.88 | 18:00 | 103a-O | GG13 | no | $B$=19.2 |
| 1.82 | 3863 | 09.12.88 | 19:00 | 103a-O | GG13 | no | $B$=18.4 |

The Andromeda galaxy has been frequently observed by Asiago telescopes for half a century, mainly to search for novae within a long term program lead by late Leonida Rosino (cf. Rosino 1973). More than 30 plates of M31 were collected in 1967, and similarly in adjacent years.

Particularly useful are the plates taken at the Newton focus of the 1.22 m telescope. It has a much larger aperture and longer focal length (6 m) than the Sharov's 50 cm Maksutof camera, and its plates routinely show stars fainter than $B$=20 mag close to the position of M31-RV (the limit away from the bright background of the bulge of the Andromeda galaxy is generally one magnitude fainter).

The 1.22 m plates rule out the outburst of M31-RV in 1967 announced by Sharov (1990). Particularly useful is a plate taken on Aug 11 (cf. Table 4), when M31-RV should have been at $B$ ∼18.7 according to Sharov. Nothing is present at the M31-RV position down to the local plate limit of $B$=20.5. According to the 50 years covered by Asiago plates, the only recorded event is that of 1988. It is worth noting that Goranskii et al. (2002) have in-

**Table 5.** Compilation of all available optical and IR photometry of the 1988 outburst of M31-RV. Only direct measurements are retained, derived or inferred ones being ignored.

| *date* | *JD* | *B* | *V* | $R_C$ | $I_C$ | *J* | *H* | *K* | *L* | $N_{H_\alpha}$ | *reference* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 02 88 | 2447205 | >19.2 | | | | | | | | | Sharov (1990) |
| 25 06 88 | 2447338 | 18.5 | | | | | | | | | Sharov (1990) |
| 21 07 88 | 2447363.97 | 17.3 | | | | | | | | | Bryan et al. (1992) |
| 09 08 88 | 2447382.92 | 17.9 | | | | | | | | | Bryan et al. (1992) |
| | 2447382.96 | 18.0 | | | | | | | | | Bryan et al. (1992) |
| 12 08 88 | 2447386.50 | | | 15.0 | | | | | | | this paper |
| 18 08 88 | 2447391.9 | 17.60 | | | | | | | | 14.88 | Tomaney et al. (1992) |
| 05 09 88 | 2447409.7 | 17.80 | | 15.54 | | | | | | 14.98 | Tomaney et al. (1992) |
| | 2447409.9 | | $g$=16.9 | $r$=15.6 | $i$=14.9 | | | | | | Rich et al. (1989) |
| | 2447409.9 | | | 15.59 | | | | | | 15.01 | Tomaney et al. (1992) |
| | 2447410 | 18.7 | | | | | | | | | Sharov (1990) |
| 06 09 88 | 2447410.98 | 17.85 | | | | | | | | | Tomaney et al. (1992) |
| 07 09 88 | 2447412.56 | | | 15.3 | | | | | | | this paper |
| 10 09 88 | 2447415 | 18.2 | | | | | | | | | Sharov (1990) |
| 12 09 88 | 2447417 | 18.6 | | | | | | | | | Sharov (1990) |
| 13 09 88 | 2447418 | 18.3 | | | | | | | | | Sharov (1990) |
| 14 09 88 | 2447419 | 18.6 | | | | | | | | | Sharov (1990) |
| 15 09 88 | 2447419.76 | 18.1 | | | | | | | | | Bryan et al. (1992) |
| | 2447420 | 18.6 | | | | | | | | | Sharov (1990) |
| 16 09 88 | 2447421 | 18.6 | | | | | | | | | Sharov (1990) |
| 17 09 88 | 2447422 | 19.0 | | | | | | | | | Sharov (1990) |
| 20 09 88 | 2447424.8 | | | 15.73 | | | | | | 15.34 | Tomaney et al. (1992) |
| 21 09 88 | 2447425.9 | | | | | 12.87 | 12.23 | 12.01 | | | Rich et al. (1989) |
| 29 09 88 | 2447433.84 | | | | | | | | | 15.80 | Ciardullo et al. (1990) |
| 30 09 88 | 2447434.63 | | | | | | | | | 15.95 | Tomaney et al. (1992) |
| 02 10 88 | 2447436.7 | 19.35 | 17.46 | 16.44 | | | | | | 16.13 | Tomaney et al. (1992) |
| 04 10 88 | 2447439 | >19.2 | | | | | | | | | Sharov (1990) |
| 13 10 88 | 2447447.68 | >19.6 | | | | | | | | | Bryan et al. (1992) |
| 15 10 88 | 2447449.90 | >19.5 | | 18.73 | | | | | | 18.27 | Tomaney et al. (1992) |
| 18 10 88 | 2447452.6 | | | 19.56 | | | | | | 19.07 | Tomaney et al. (1992) |
| | 2447452.9 | | | | 17.2 | | | | | | Mould et al. (1990) |
| | 2447453 | | | | $i$=17.97 | | | | | | Rich et al. (1989) |
| 20 10 88 | 2447454.92 | | | 19.78 | | | | | | | Tomaney et al. (1992) |
| 24 10 88 | 2447458.9 | | | | 18.4 | | | | | | Mould et al. (1990) |
| 25 10 88 | 2447459.7 | | | | | 14.1 | | 12.8 | 12.0 | | Mould et al. (1990) |
| 01 11 88 | 2447466.61 | >20.5 | | | | | | | | | Tomaney et al. (1992) |
| 02 11 88 | 2447467.68 | | | | | | | | | 19.24 | Tomaney et al. (1992) |
| 06 11 88 | 2447471.8 | | | | >18.6 | | | | | | Mould et al. (1990) |
| 19 11 88 | 2447484.6 | | | | | 15.87 | 14.77 | 14.0 | 12.6 | | Mould et al. (1990) |
| 25 06 89 | 2447702.7 | | | | | >16.8 | | >15.6 | | | Mould et al. (1990) |
| 03 07 89 | 2447710.8 | | | | >19.3 | | | | | | Mould et al. (1990) |

spected archive plates spanning the time interval 1949–1994 in search for previous outburst of V838 Mon, and found none.

The region of the bulge where M31-RV appeared is characterized by subtle dust lanes and a knotty surface brightness distribution. It is possible that the Crimean 50 cm Maksutof camera had trouble resolving the local inhomogeneities of the bulge brightness distribution, which could have been confused for M31-RV on the 1967 plates. Alternative possibilities, such as a gravitational lensing event or the appearance of a nova close to the position of M31-RV do not apply because they should have been easily visible on the deeper Asiago plates. It is worth noting that the Asiago 1.22 m telescope discovered a sizable fraction of all novae cataloged in M31 during the 1960's.

## 4. The 1988 outburst

### 4.1. Evolution

Table 5 collects all direct photometric observations that we have been able to locate in literature concerning the 1988 outburst of M31-RV. Two $R_C$ entries (cf. Table 3) come from the present inspection of plates from the Asiago archive. By far, the best covered photometric bands are $B$, $R_C$ and $N_{H_\alpha}$. The latter has been obtained with a narrow filter centered on H$\alpha$ and characterized by a full width at half maximum (FWHM) of 75 Å. Their light-curves are presented in Figure 2. The $R_C$ and $N_{H_\alpha}$ match well because the H$\alpha$ displayed a modest emission, with negligible effect on the total flux through both $R_C$ and $N_{H_\alpha}$ filters. More relevant is instead the fact that the position of H$\alpha$ and therefore of the $N_{H_\alpha}$ filter is centered on the contin-

uum that in M stars tries to emerge between the 6200 and 6700 Å TiO bands. $N_{\mathrm{H}_\alpha}$ tends to appear brighter compared to $R_\mathrm{C}$ as the spectral type progresses from M0 to M5. At later spectral types the two bands converge back to similar values because the rapidly increasing steepness of the spectrum increases the flux in the red wing of the $R_\mathrm{C}$ band. The small differences in Figure 2 between the $R_\mathrm{C}$ and $N_{\mathrm{H}_\alpha}$ branches therefore seem to just reflect the monotonic evolution toward later M spectral types of the M31-RV continuum.

The $R_\mathrm{C}$ lightcurve of M31-RV is less scattered compared to the $B$ lightcurve for a number of reasons. The literature $R_\mathrm{C}$ data come mainly from CCD observations, and the two Asiago $R_\mathrm{C}$ data-points are relative to a comparison sequence calibrated via CCD observations. The comparison sequences used in the literature to derive $B$ data are of unknown origin. Furthermore, the $R_\mathrm{C}$ data are obtained with accurate detector + filter pairs well matching the standard system, while several of the $B$ band data-points are not color corrected or come from scattered emulsion+filter combinations (which are relevant in the case of the very red colors displayed by M31-RV). Finally, the contrast between M31-RV and the background bulge brightness was more favorable in $R_\mathrm{C}$ than in $B$.

The striking similarity of the $R_\mathrm{C}$ light-curves of M31-RV and V838 Mon is evident in Figure 2 (V838 Mon $R_\mathrm{C}$ data are taken from Munari et al. 2002c and Bond et al. 2003). The comparison is obviously limited to the portion of the lightcurve of M31-RV covered by the observations (while the V838 Mon one extends well beyond the small displayed section). Both objects, after a plateau phase characterized by a slowly evolving K-type spectrum, experienced a sudden drop of several magnitudes (reaching $\Delta R_\mathrm{C}$=0.2 mag day$^{-1}$ for M31-RV and $\Delta R_\mathrm{C}$=0.3 mag day$^{-1}$ for V838 Mon) accompanied by a corresponding temperature drop as indicated by the spectral type sweeping quickly through the M-type sequence toward classifications so far seen only in brown *dwarfs* (cf. Evans et al. 2003). As evident from the evolution of reddening and spectral energy distribution discussed in following sections, the drop in magnitude of M31-RV is not due to dust condensation in the ejecta, but instead mainly due to drop in temperature during the expansion (shifting progressively the emission peak toward the IR) and to an overall decrease in luminosity.

### 4.2. Reddening

From available data it is possible to estimate at different epochs the reddening affecting M31-RV.

At the time of the *JHK* observation from of Sep 21, 1988 reported in Table 5, the spectral type of M31-RV was close to M2 (cf. Figure 2). According to Frogel and Whitford (1987), the intrinsic color of M2 giants in the Bulge of our Galaxy (taken to resemble their counterparts in the Bulge of M31, with comparable ages and metallicities, cf. Davidge 2001) is $(J-K)_\circ$=0.81. Compared with the observed $J-K$=0.86 for M31-RV, it implies $E_{J-K}$=0.05. The relation between $E_{J-K}$ and $E_{B-V}$ for M2 giants in the KPNO infrared system is (Fiorucci and Munari 2003):

$$\frac{E_{J-K}}{E_{B-V}} = 0.596 + 0.005 \times E_{B-V} \tag{1}$$

and the corresponding reddening toward M31-RV is therefore $E_{B-V}$=0.08. At the time of the infrared observations of Oct 25, 1988, the spectral type was ∼M7, for which $(J-K)_\circ$=1.23 (again from Frogel and Whitford 1987). Compared with the observed $J-K$=1.30 it gives $E_{J-K}$=0.07 and correspondingly $E_{B-V}$=0.12. The latest IR observation in Table 5 cannot be used because the spectral classification at that time is unknown (by analogy with V838 Mon it was probably later than M10).

By the time M31-RV was passing through the shoulder of the $R_\mathrm{C}$ lightcurve in Figure 2 (JD∼2447418), the optical color was $B-R_\mathrm{C}$ ≈+3.1 and the spectral type ∼M1. From Kurucz models computed on purpose for the M31 bulge metallicity ([Fe/H]=−0.2), the intrinsic color of an M1 supergiant is $B-R_\mathrm{C}$=2.79. The excess is therefore $E_{B-R}$=0.31. The transformation relation between $E_{B-R}$ and $E_{B-V}$ (both in the Landolt realization of the Johnson and Cousins systems) for early M giants and a normal extinction law ($R_V = A_V/E_{B-V} = 3.1$) is (from Fiorucci and Munari 2003):

$$\frac{E_{B-R}}{E_{B-V}} = 2.044 + 0.099 \times E_{B-V} \tag{2}$$

This gives $E_{B-V}$=0.15 for M31-RV.

The three independent determinations consistently converge toward:

$$E_{B-V} = 0.12 \ \pm 0.02 \tag{3}$$

as the reddening affecting M31-RV, with no indication of any significant increase during the abrupt photometric descent from optical maximum brightness of M31-RV, which cannot therefore be ascribed to dust condensation in the ejecta. A sizable fraction of the total reddening affecting M31-RV arises in our own Galaxy. In fact, the Burnstein and Hales (1982) extinction maps report $E_{B-V}$ ∼0.1 as the total Galactic extinction along the line of sight to M31.

### 4.3. Absolute magnitude

The distance modulus to M31 has been recently determined as 24.49±0.11 mag by Joshi et al. (2003) and as 24.47±0.08 mag by Stanek and Garnavich (1998). Taking the average of 24.48 mag and the $E_{B-V}$ = 0.12 reddening from the previous section, the absolute magnitude of M31-RV at peak $R_\mathrm{C}$ brightness around Aug 15, 1988 ($R_\mathrm{C}$ ∼14.94) is $M_{R_C}$ ∼ −9.88. The true maximum could have been even brighter because the lightcurve is not completely mapped. Repeating the exercise for the $B$ band, the maximum can be estimated to have occurred around JD 2447362 at $B$=17.4, to which it corresponds $M_B$=−7.7.

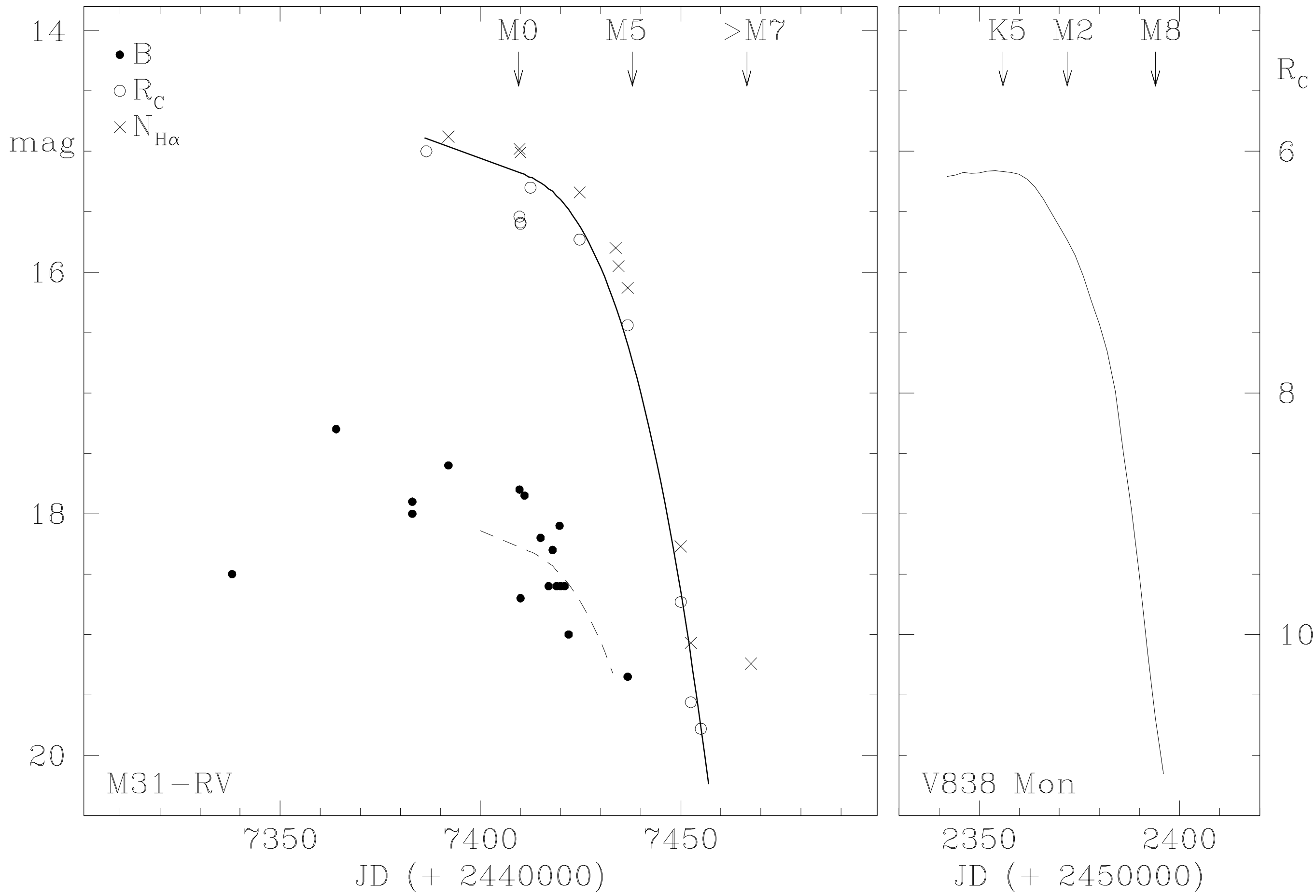


**Fig. 2.** Photometric and spectroscopic evolution of M31-RV (spectral classifications from Rich et al. 1989 and Mould et al. 1990). The corresponding section of the $R_C$ lightcurve of V838 Mon is shown for comparison on the same scale (spectroscopic classification from Munari et al. 2002c).

The bolometric correction and $V - R_C$ for M0 supergiants are $-1.29$ and $+0.97$, respectively (Drilling and Landolt 2000). According to Figure 2, M31-RV was at $R_C \sim 15.2$ by the time it was classified M0 by Rich et al. (1989), which implies $M_{bol} \sim -9.95$ and $L \sim 7.5 \times 10^5$ L$_\odot$, i.e. one of the brightest stars in M31 and the whole Local Group.

### *4.4. An universal eruption mechanism ?*

The striking photometric and spectroscopic similarities between M31-RV and V838 Mon suggest a similar outburst mechanism. The absolute magnitude reached by the two events also seems quite similar.

Figure 2 indicates that both M31-RV and V838 Mon when transitioning from the plateau to the rapid fading phase were displaying a ~M1 supergiant spectrum. At that time, the absolute magnitude of M31-RV was $M_{R_C} \approx -9.6$. At the corresponding time the magnitude of V838 Mon was $R_C$=6.2. The reddening affecting V838 Mon is uncertain, but a fair estimate is $E_{B-V}$=0.5 (cf. Munari et al. 2002a). Assuming the same absolute magnitude of M31-RV, this corresponds to a distance $d_{\rm V838\ Mon} = 8$ kpc. This value is in good agreement with the average of the distance determinations by Bond et al. (2003) based on the HST imaging of the V838 Mon light echo, and Munari et al. (2002b) spectrophotometric distance to the B3 V component in the V838 Mon binary. Therefore the photometric and spectroscopic evolution of V838 Mon and M31-RV were similar, as well as the absolute magnitude at the time the drop in temperature occurred.

Such similarities are remarkable in view of the different ages and evolution histories of the two objects. M31-RV appeared in the Bulge of M31, which is characterized by a turn-off mass around 1 M$_\odot$ and a high metallicity [Fe/H]=−0.2. V838 Mon appears instead to be young and massive (the companion to the erupted component is a B3 V star) and it is located in the outskirts of the galactic disk, at galacto-centric distances of 15-17 kpc, where the metallicity is lower and of the order of [Fe/H]=−0.6 (cf. Davidge 2001). Yet, the two events show the same evolution and absolute luminosity in $R_C$. This seems to suggest that an *universal* explosion mechanism could have powered both events, a mechanism independent from the way in which a stellar system reaches it. The independence of the outcome from the initial conditions is a characteristic, for example, of models of SN Ia, well known for their ho-

mogeneity in absolute magnitude and lightcurve shapes. In SN Ia, a WD reaches the Chandrasekhar mass and ignites carbon burning, irrespective of whether a merger of two WDs or the accretion on a single WD from a non-degenerate companion occurred. Here we postulate that a common eruption mechanism must have powered both M31-RV and V838 Mon, the outcome of which was not affected by the large differences in metallicity, age and mass of the two objects.

The theoretical models so far published do not seem able to explain both M31-RV and V838 Mon, as well as the similarity of the two events. The Iben and Tutukov (1992) TNR mechanism cannot work in V838 Mon, because the young age implied by the presence of a B3V star in the system is too short for a WD to cool and accrete enough material at a very low accretion rate. Both Soaker and Tylenda (2003) and Retter and Marom (2003) suggestions of swallowed stellar or planetary companions by an expanding giant seem unable to account for the strong similarities exhibited by M31-RV and V838 Mon. The results presented in this paper therefore support the need of a radically new model if M31-RV, V838 Mon and V4332 Sgr are to be explained as a *homogeneous class* of astronomical objects.

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